SECURITY CLASSIFICATION: UNCLASSIFIED

COMPONENTS R&D LABORATORIES

POWER PLANT LABORATORY

TITLE OF PROJECT: PERFORMANCE OF CODE T-22 TEMPERATURE CONTROLLED, VARIABLE SPEED FLUID COUPLING FOR FAN DRIVE

REPORT NO. 7964 (FINAL) COPY NO. 25

WRITTEN BY: REVIEWED BY:

Carl C. Lorentzen Lee A. Smith

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DATE OF REPORT 15 July 1963

EXPENDITURE ORDER: 3717-01-37

~~COL SHEET~~ INCLOSED

MOBILITY

U.S. ARMY TANK-AUTOMOTIVE CENTER
CENTER LINE, MICHIGAN

SECURITY CLASSIFICATION: UNCLASSIFIED

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POWER PLANT LABORATORY

TITLE OF PROJECT: Performance of Code T-22 Temperature Controlled, Variable Speed Fluid Coupling to Fan Drive

REPORT NO. 7964 (Final) DATE: 15 July 1963

EXPENDITURE ORDER NO. 3717-01-37

WRITTEN BY Carl C. Lorentzen
CARL C. LORENTZEN

REVIEWED BY Lee A. Smith
LEE A. SMITH

ABSTRACT

Report No. 7964 (Final)

1. Purpose: Determine the following performance characteristics of Code T-22 variable speed fluid coupling:

a. Output horsepower and torque at input speeds from 1200 to 4000 rpm with 2, 3, 5, 10, 25 and 50 percent slip.

b. Percent slip driving F-78 fan at simulated loads.

c. Response of fording and temperature controls.

d. Endurance.

2. Method: Dynamometers were used to determine output horsepower and torque characteristics with respect to input speeds. With fluid coupling driving Code F-78 fan the following was determined:

a. Responses of fording and temperature controls.

b. Endurance testing was completed for 100 hours at fan speeds from 1200 to 2800 rpm.

3. Results:

a. Performance of Code T-22 fluid coupling was as follows:

(1) Output torque was 49 lb-ft at 2 percent slip with input speed at 4400 rpm and 91 lb-ft at 3 percent slip.

(2) Output horsepower was 40 at 2 percent slip with input speed at 4400 rpm and 74 at 3 percent slip.

(3) The slip was 2 percent when driving Code F-78 fan at input speeds from 1200 to 4800 rpm.

b. The temperature control started increase of fan speed at 187 F.

c. Response time of fording control was a maximum of 22 seconds to reduce fan speed from 4710 to 450 rpm.

d. Code T-22 fluid coupling withstood the 100 hour endurance test without any failures.

4. Conclusions: The performance and durability of Code T-22 variable speed fluid coupling was satisfactory. The control system as provided was unreliable. The control as modified functioned, but durability was not determined.

5. Recommendations: Redesign control system and test for durability and reliability. Conduct a test of cooling control on a power package.

POWER PLANT LABORATORY

Report No. 7964 (Final)
Date: 15 July 63

PROJECT TITLE: Performance of Code T-22 Temperature Controlled, Variable Speed Fluid Coupling for Fan Drive.

INTRODUCTION

A variable speed fluid coupling was submitted for determination of performance characteristics. This fluid coupling was proposed for driving the fan of a cooling system for the power plant of the Main Battle Tank. The fluid coupling was provided with a hydraulic control to vary the fan speed from idle to maximum at a minimum engine oil pressure of 15 psig. Maximum output speed varied with input speed and output load. The hydraulic control was activated by a temperature sensing assembly. An electrically operated control was provided to stop the fan during deep water fording.

The fluid coupling was tested to determine output horsepower and torque characteristics, speed loss (percent slip) driving a fan at simulated loads, response of fording and temperature controls, and endurance for 100 hours. This report presents the results of these tests.

OBJECT

Determine the following performance characteristics of Code T-22 variable speed fluid coupling:

1. Output horsepower and torque at input speeds from 1200 to 4400 rpm with 2, 3, 5, 10, 25 and 50 percent slip.

2. Percent slip driving Code F-78 at simulated loads.

3. Response of fording and temperature control.

4. Endurance for 100 hours.

SUMMARY

1. Performance of Code T-22 variable speed fluid coupling was as follows:

a. Output torque was 49 lb-ft at 2 percent slip with input speed at 4400 rpm and 91 lb-ft at 3 percent slip.

b. Output horsepower was 40 at 2 percent slip with input speed at 4400 rpm and 74 at 3 percent slip.

c. The slip was 2 percent when driving Code F-78 fan at input speeds from 1200 to 4800 rpm with modified hydraulic control.

2. Response of temperature control with modified hydraulic control was as follows:

a. Upon increasing control temperature, fan speed started to increase at 187 F; it was maximum for a particular input speed at 195 F.

b. Upon decreasing control temperature, fan speed started to decrease at 193 F and decreased to idle at 187 F.

3. The original hydraulic control failed to operate for all fording and temperature control response tests.

4. Response of fording control with modified hydraulic control was a maximum of 22 seconds to reduce fan speed from 4710 to 450 rpm.

5. Code T-22 fluid coupling withstood conditions of an endurance test for 100 hours without any failures.

6. Maximum rate of heat transfer into oil was 249 BTU per min. with input speed of 4800 rpm and fan speed of 3240 rpm (partial engagement).

CONCLUSIONS

1. The performance and durability of Code T-22 variable speed fluid coupling was satisfactory.

2. The control system provided was unreliable.

3. The control system as modified functioned but durability of the system was not determined.

RECOMMENDATIONS

Redesign control system and test for durability and reliability. Conduct a test of cooling control on a power package.

TEST MATERIAL

1. Code T-22 variable speed fluid coupling (Figures 1 and 2). Figure 3 is a schematic of the originally provided temperature control system. The fluid coupling was provided with a temperature control system to actuate the hydraulic control for varying the fan speed. The temperature sensing assembly consisted of a capillary tube connected to a bellows filled with monochlorobenzene. The control was designed to increase the fan speed at engine coolant temperature of 170 F minimum, to allow maximum speed at 210 F maximum, and to reduce to idle speed at 160 F maximum. A fail-safe control was provided to produce maximum fan speed in case of failure of the temperature sensing assembly. This control was designed to operate at an engine coolant temperature of 210 to 230 F. Figure 4 is a schematic of the modified temperature control system tested. The modification simplified the control assembly by elimination of the directional valve and fail-safe valve. The modified control system was designed to prevent a decrease of fan speed at temperature above 205 F.

2. Code F-78 fan.

3. Oil, MIL-L-2104A, Grade 10, dated 6 May 1954.

TEST EQUIPMENT

1. Test Cell No. 8, Bldg. 212, Detroit Arsenal.

2. Motoring dynamometer, General Electric Co. Type TL.C 2556M, Model 266374, 200 hp capacity at speeds from 2500 to 5000, rpm Dynamometer Constant 4340.

3. Absorption dynamometer, Mid-West Dynamometer, Dynamic Corp. Type 1519, 300 hp capacity at speeds from 1000 to 4000 rpm, Dynamometer Constant 3000.

4. Air duct with orifice at outlet, 2 ft diameter, 8 ft length.

5. Miscellaneous components required: An oil pump, filter, 10 gallon reservoir, pressure regulator, and heat exchangers to provide

oil to fluid coupling at regulated oil pressure and temperature.

6. Calibration Bath, Hallekainen Instruments (containing silicone oil) equipment with mixer, heater and cooler for applying temperature to the control sensers.

7. Instrumentation

a. Chronotachometers, Standard Electric Time Corp., for measuring input and output speeds.

b. Toledo Scale for measuring output load.

c. Pressure gauges for setting control and supply oil pressure.

d. Vertical manometer, Trimount Instrument Co., for measuring static air pressure at outlet of fan.

e. Photo-electric pickup, Farmer Electric Co., Berkeley universal counter, and associated equipment for measuring fan speed.

f. Recorder, Brush Instruments, Clevite Corp. for determining deceleration time of fan.

g. Thermocouples, iron-constantan, ISA Type Y and Brown pyrometer, Minneapolis Honeywell Regulator Co., for measuring temperatures.

TEST PROCEDURES

1. Test Setup

Code T-22 fluid coupling was installed in Cell 8, Bldg. 212, Detroit Arsenal. The input shaft was connected to the 200 horsepower motoring dynamometer. The output shaft was connected to a 300 horsepower absorption dynamometer. The oil pump, heat exchangers, filter, pressure regulator, reservoir, thermocouples, and valve were installed according to requirements of schematic circuit, Figure 5. The temperature and fail-safe control sensors were places in the oil bath container. Four thermocouples for measuring ambient temperature were placed at equal distances of 6 feet from the fluid coupling., Figures 6 and 7 show the test setup. After determination of output horsepower and torque characteristics, the absorption dynamometer was removed. Code F-78 fan was connected to the output shaft. The air duct with orifice was connected to the outlet of fan. The size of the orifice was selected to produce an air flow resistance of 9.5 inches of water at an air flow of 15,000 cfm with density of 0.075 lb/ft. Photo-electric pickup, Brush recorder and associated equipment was installed to determine fan speed.

2. Operating Limit

Input Torque:	100 lb ft. Maximum
Speed:	5250 rpm, Maximum
Outlet oil temperature:	275F Maximum
Control temperature:	230 F Maximum
Control oil pressure:	15 psig Maximum

3. Preparation

The reservoir was filled with MIL-L-3104A, grade 10, oil until the level was up to the return line. The control pressure and oil supply were adjusted as follows: (Refer to Figure 5)

a. Oil pump was started with Valve No. 1 open.

b. With Valve No. 2 closed, Valve No. 1 was closed until pump pressure was 40 psi.

c. With Valve No. 2 open and Valve No. 3 closed, control pressure was set at 12 to 15 psi by adjusting the pressure regulator.

d. The oil flow at outlet of fluid coupling was adjusted to 2 ± 0. 1 gpm at inlet temperature of 240 ± 5 F by opening Valve No. 3 and closing Valve No, 1 with pump pressure at 40 psi.

4. Output Horsepower and Torque Characteristics Test

Output horsepower and torque were determined under the following conditions:

a.	Ambient temperature:	85 ± 5 F
b.	Inlet Oil temperature:	240 ± 5 F
c.	Control temperature:	220 ± 5 F
d.	Oil flow:	2 ± 0.1 gpm
e.	Schedule of input and output speeds:	

Input Speed RPM	Speed loss - percent 2	3	5	10	25	50
	Output Speed - RPM					
1200	1176	1164	1140	1080	900	600
1600	1568	1552	1520	1440	1200	800
2000	1960	1940	1900	1800	1500	1000
2400	2352	2328	2280	2160	1800	*
2800	2744	2716	2660	*	*	
3200	3136	3104	3040			
3600	3528	3492	*			
4000	3920	3880				
4400	4312	4268				

* Input torque exceeded maximum limit of 100 lb ft.

The output loads were determined with input and output speed within 1 rpm of the above schedule except the trial at 2000 rpm input speed with 50 percent speed loss. The output speed was 995 rpm instead of 1000 rpm at this condition.

5. Temperature Control Response Test

Control temperatures were determined under the following conditions:

a. Ambient temperature: 85 ± 5 F
b. Inlet oil temperature: 180 and 240 ± 5 F
c. Air flow resistance: 9.5 Inches of water at 15,000 cfm
d. Input speed: 1200 to 4800 ± 5 rpm in increments of 400 rpm at inlet oil temperature of 240 F; 2000 and 4000 rpm at inlet oil temperature of 180 F
e. Fan Speed at each input speed:

   (1) Increasing temperature to start increase of fan speed.

   (2) Increasing temperature to attain maximum fan speed.

   (3) Decreasing temperature to start decrease of fan speed.

   (4) Decreasing temperature to attain idle fan speed.

f. Application of Control Temperature:

The control temperature was decreased 5 to 10 F below the temperature which caused increase of fan speed. It was increased 5 to 10 F above the temperature to attain maximum speed.

6. Fording Control Response Test

The time interval between actuation of the fording control and decrease of fan speed to 450 rpm was measured under the following conditions:

a. Ambient Temperature: 85 ± 5 F
b. Inlet oil temperature: 240 ± 5 F
c. Control temperature: 220 ± 5 F
d. Air flow resistance: 9.5 inches of water at 15,000 cfm

The fording control was actuated by immersing the probe of the switch assembly into a container of tap water at room temperature.

7. Endurance Test

The fluid coupling was operated for 100 hours at the following conditions:

a. Ambient temperature: 90 ± 10 F
b. Inlet oil temperature: 240 ± 5 F
c. Control temperature: 220 ± 5 F
d. Air flow resistance: 9.5 inches of water at 15,000 cfm
e. Input speed schedule:

PERIOD	INPUT SPEED RPM	TEST TIME HOURS
1	1200	2
2	1600	2
3	2000	2
4	2400	2
5	2800	2
6	3200	2
7	3600	2
8	4000	2
9	4400	2
10	4800	2
11	1600	8
12	2400	8
13	3200	8
14	4000	8
15	4800	8
16	2400	10
17	3200	10
18	4000	10
19	4800	10

The hydraulic control assembly was not subjected to the endurance test. It had been removed for modification. This test was performed with a manual valve used in place of the automatic control valve to actuate the scoop tube.

8. Heat transfer load test of Code T-22 Fluid Coupling Driving Code F-78 Fan.

The amount of heat that was absorbed by the oil in the fluid coupling was determined under the following conditions:

a. Ambient temperature: 95 ± 5 F
b. Inlet oil temperature: 240 ± 5 F
c. Oil flow: 2 ± 0.1 gpm
d. Air flow resistance: 9.5 inches of water at 15,000 cfm
e. Fan speed: 605, 965, 1530, 3240, 3550, and 4700 rpm.

RESULTS AND DISCUSSION

1. Output Horsepower and Torque Characteristics

Figures 8 and 9 show output torque characteristics of Code T-22 fluid coupling with respect to input speed. Curves for 5 and 10 percent slip (speed loss) of Figure 8 were extrapolated by determining input speed at output torque of 100 lb - ft from the extended lines in the logarithmic plot, Figure 7. The output torque was 49 lb-ft at 2 percent slip with input speed at 4400 rpm; it was 91 lb - ft at 3 percent slip. The output torque was 103 lb-ft at 25 percent slip with input speed at 2400 rpm. Extrapolations show that the output torque would be 100 lb-ft at 5 percent slip with input speed at 3600 rpm and at 10 percent slip with input speed at 2800 rpm. The curve for 50 percent slip shows that the threshold of stalling is between input speeds of 1600 and 2000 rpm. With a change in input speed from 1600 to 2000 rpm, the output load was decreased to increase the output speed to the required speed for 50 percent slip.

Figure 10 shows output horsepower characteristics of Code T-22 fluid coupling with respect to input speed. The output horsepower was 40 at 2 percent slip with input speed at 4400 rpm. It was 74 HP at 3 percent slip of with input speed at 4400 rpm.

Figure 11 shows percent slip of Code T-22 fluid coupling driving Code F-78 fan with respect to input speed with air flow resistance of 9.5 inches of water at 15,000 cfm. The slip was very nearly 2 percent at input speeds from 1200 to 4800 rpm. This shows that the fluid coupling is suitably matched to efficiently drive Code F-78 fan.

2. Temperature Control Response

The response of fan speed was as follows:

	CONTROL TEMPERATURE F			
Input Speed RPM + 5	Start of Fan Speed Increase	Fan Speed Maximum	Start of Fan Speed Decrease	Fan Speed Decreses To Idle
1200	187	195	196	185
1600	188	195	191	185
2000	188	198	195	184
2000*	190	196	193	184
2400	187	196	192	189
2800	188	195	193	189
3200	185	194	192	189
3600	185	195	192	188
4000	185	193	192	189
4000*	188	198	195	189
4400	187	--	190	--
4800	188	195	194	--

*Inlet oil temperature at 180 $\pm$ 5 F. All other tests with inlet oil temperature at 240 $\pm$ 5 F.

The data shows that speed and oil temperature did not affect the temperatures of response. The slight difference of the temperatures could be attributed to variation of friction of scoop tube.

The above tests were run after the control assembly had been modified and adjusted by the manufacturer.

3. Fording Control Response

The response of the fording control to decrease the fan speed to 450 rpm by immersing the probe of the switch assembly into a container of tap water at room temperature was as follows:

Input Speed RPM + 5	Initial Fan Speed-RPM	Response Time Seconds
1200	1170	14
1600	1565	18
2000	1965	16
2400	2360	17
2800	2745	21
3200	3130	19
3600	3525	20
4000	3910	20
4400	4310	21
4800	4710	22

4. Endurance

The Code T-22 Fluid Coupling withstood the conditions of an endurance test for 100 hours without any failures.

5. Heat Transfer Load of Code T-22 Fluid Coupling Driving Code F-78 Fan

The rate of heat transfer into oil at a flow of 2 gpm with input speed at 4800 rpm was as follows:

FAN SPEED RPM	TEMPERATURES F AMBIENT	INLET OIL	OUTLET OIL	HEAT** TRANSFER RATE BTU/Min
4700	92	241	230	-88
3550	95	243	265	177
3240	98	236	267	249
1530	97	237	245	64
965	95	237	239	16
605	93	238	230	-64
4703*	79	241	239	-16

*Data taken from output horsepower and torque test at 2% slip without fan.

**Specific heat 0.55 BTU/lb: Oil flow at 14.6 lb/minute.

The rate of cooling by air flow of fan was 72 BTU/min. This rate was derived from the above data as the difference of outlet oil temperatures with and without the fan. This explains the negative values in the chart which indicate cooling of the oil in the fluid coupling instead of heating.

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COMPONENTS RESEARCH AND DEVELOPMENT LABORATORIES
Power Plant Laboratories

TECHNICAL REPORT DISTRIBUTION

Date: 15 July 1963 Report No. 7964

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LIST OF INCLOSURES

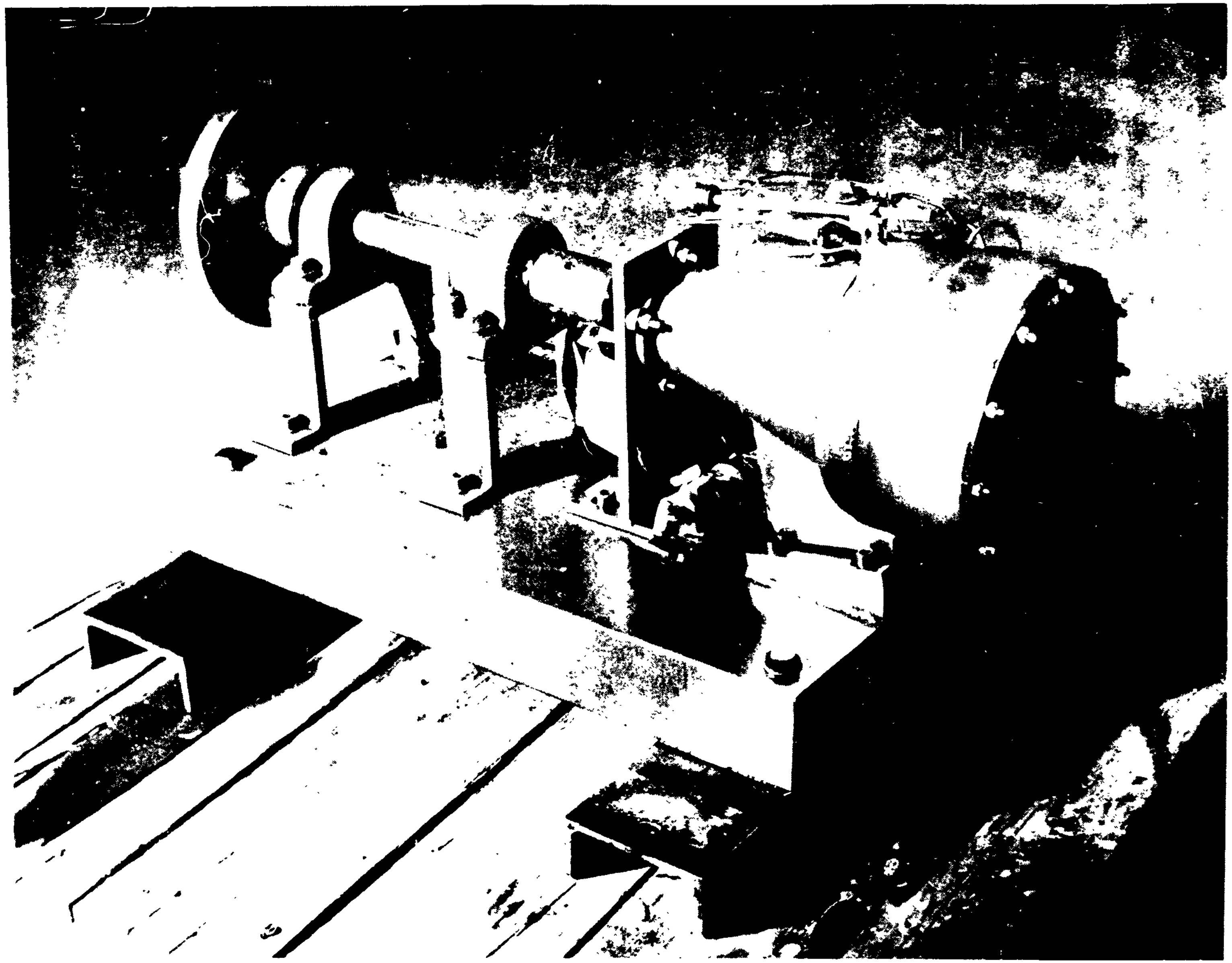
Report No. 7964 (Final)

	Inclosure No.
Figure 1 - Code T-22 Variable Speed Fluid Coupling, Neg. No. 71732	1
Figure 2 - Code T-22 Variable Speed Fluid Coupling, Neg. No. 71733	2
Figure 3 - Schematic - Original Temperature Control System	3
Figure 4 - Schematic - Modified Temperature Control System	4
Figure 5 - Schematic Circuit of Oil Supply. . . .	5
Figure 6 - Test Setup of Code T-22 Fluid Coupling, Neg. No. 71449	6
Figure 7 - Test Setup of Code T-22 Fluid Coupling, Neg. No. 71448	7
Figure 8 - Output Torque Characteristics of Code T-22 Fluid Coupling	8
Figure 9 - Output Torque Characteristics of Code T-22 Fluid Coupling.	9
Figure 10 - Output Horsepower Characteristics of Code T-22 Fluid Coupling	10
Figure 11 - Percent Slip of Code T-22 Fluid Coupling Driving Code F-78 Fan	11
Expenditure Order 3717-0137, dated 19 September 1962	12

Incl

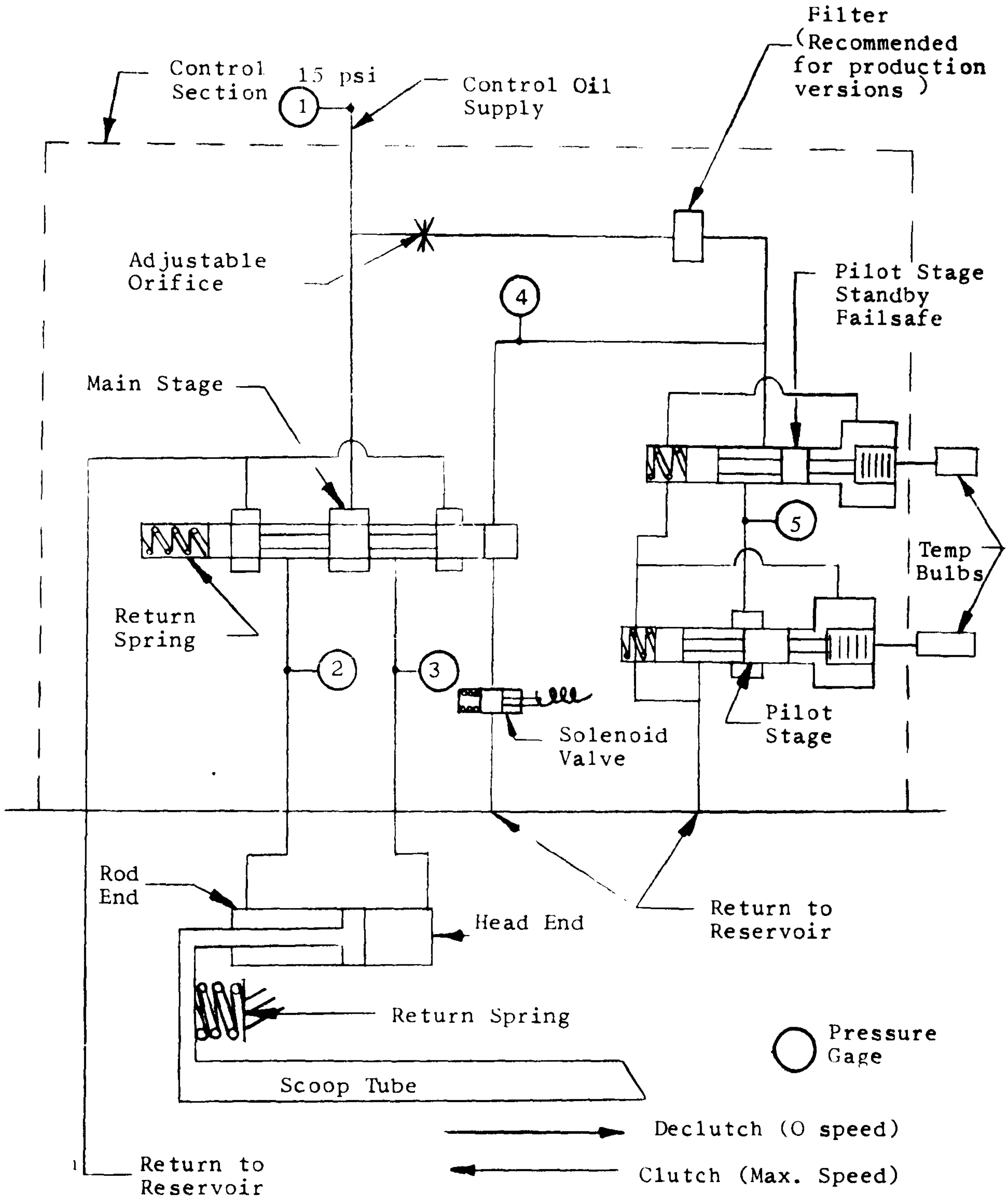
CODE T-22 VARIABLE SPEED FLUID COUPLING

FIGURE 1



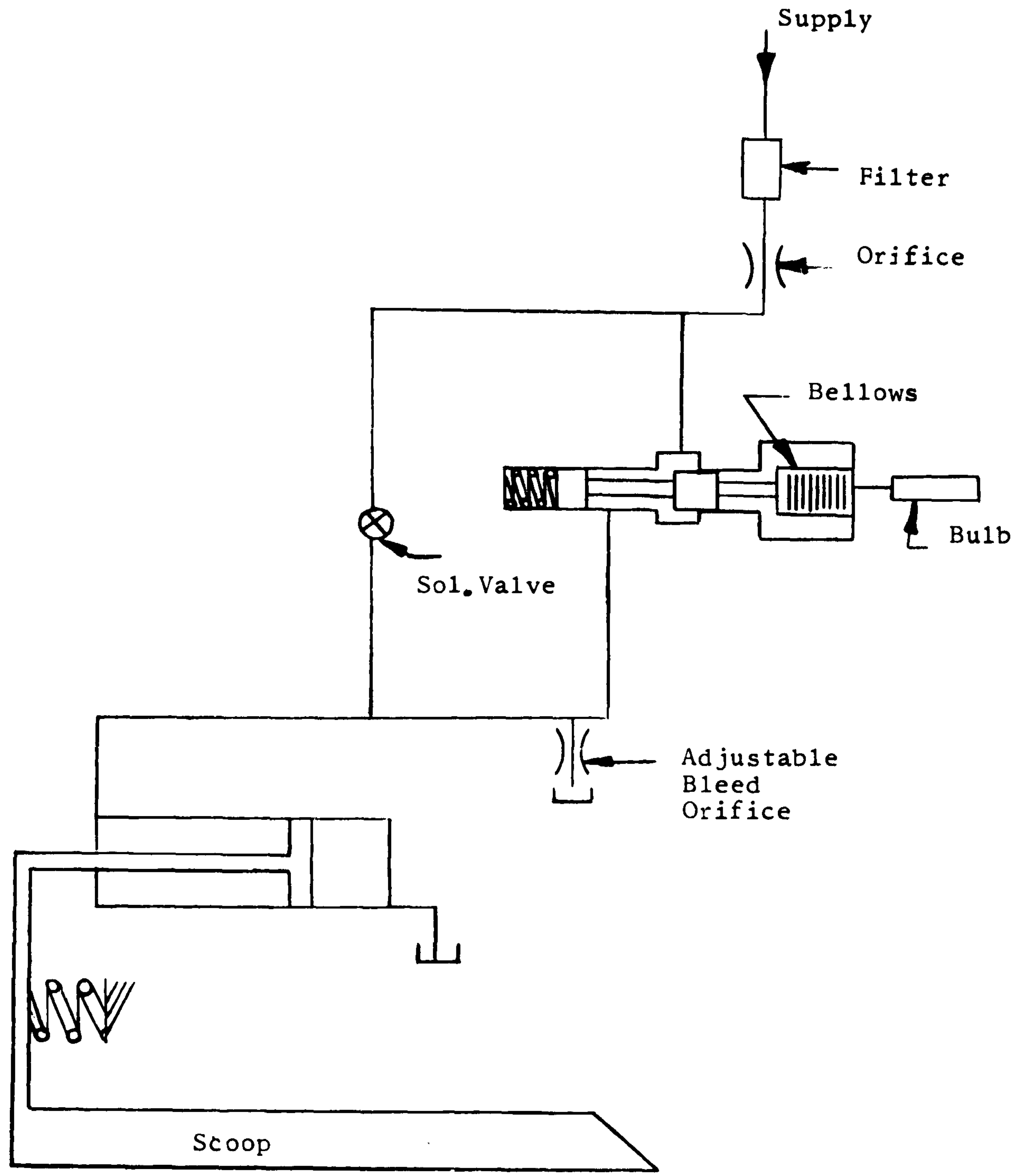
CODE T-22 VARIABLE SPEED FLUID COUPLING

FIGURE 2



ORIGINAL TEMPERATURE CONTROL SYSTEM

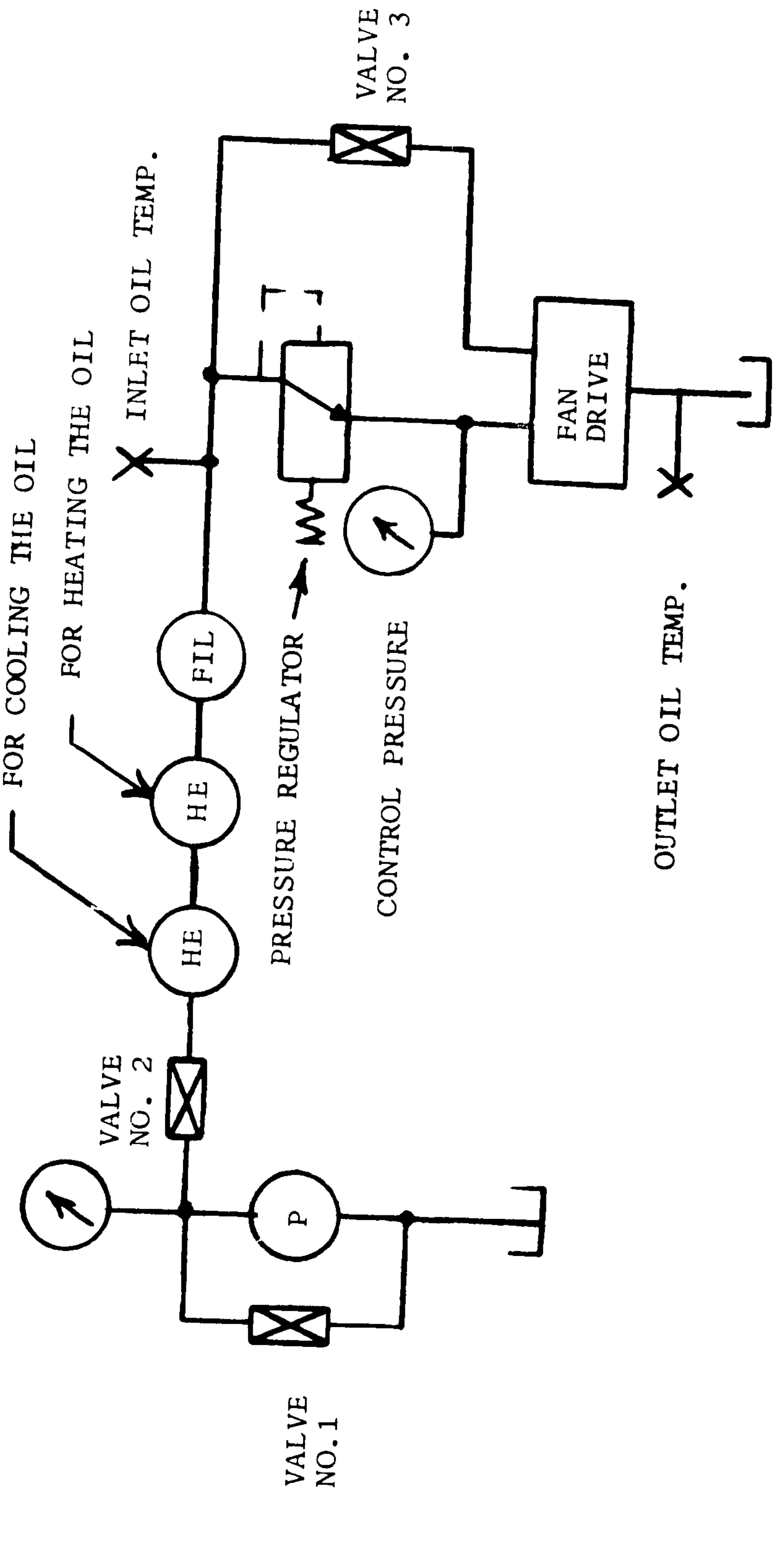
FIGURE 3



MODIFIED TEMPERATURE CONTROL SYSTEM

FIGURE 4

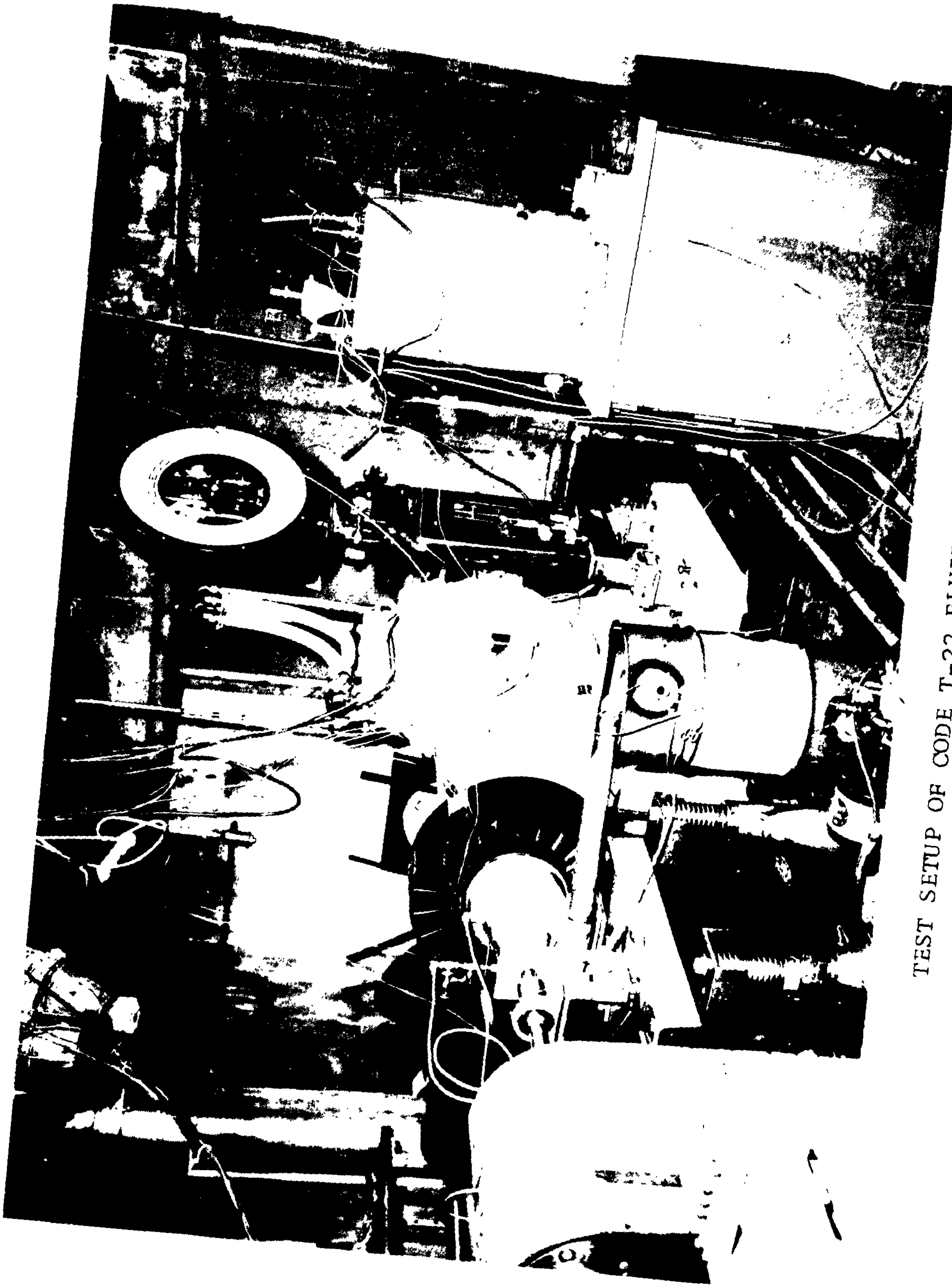
Inclosure 4



SCHEMATIC CIRCUIT OF OIL SUPPLY

FIGURE 5

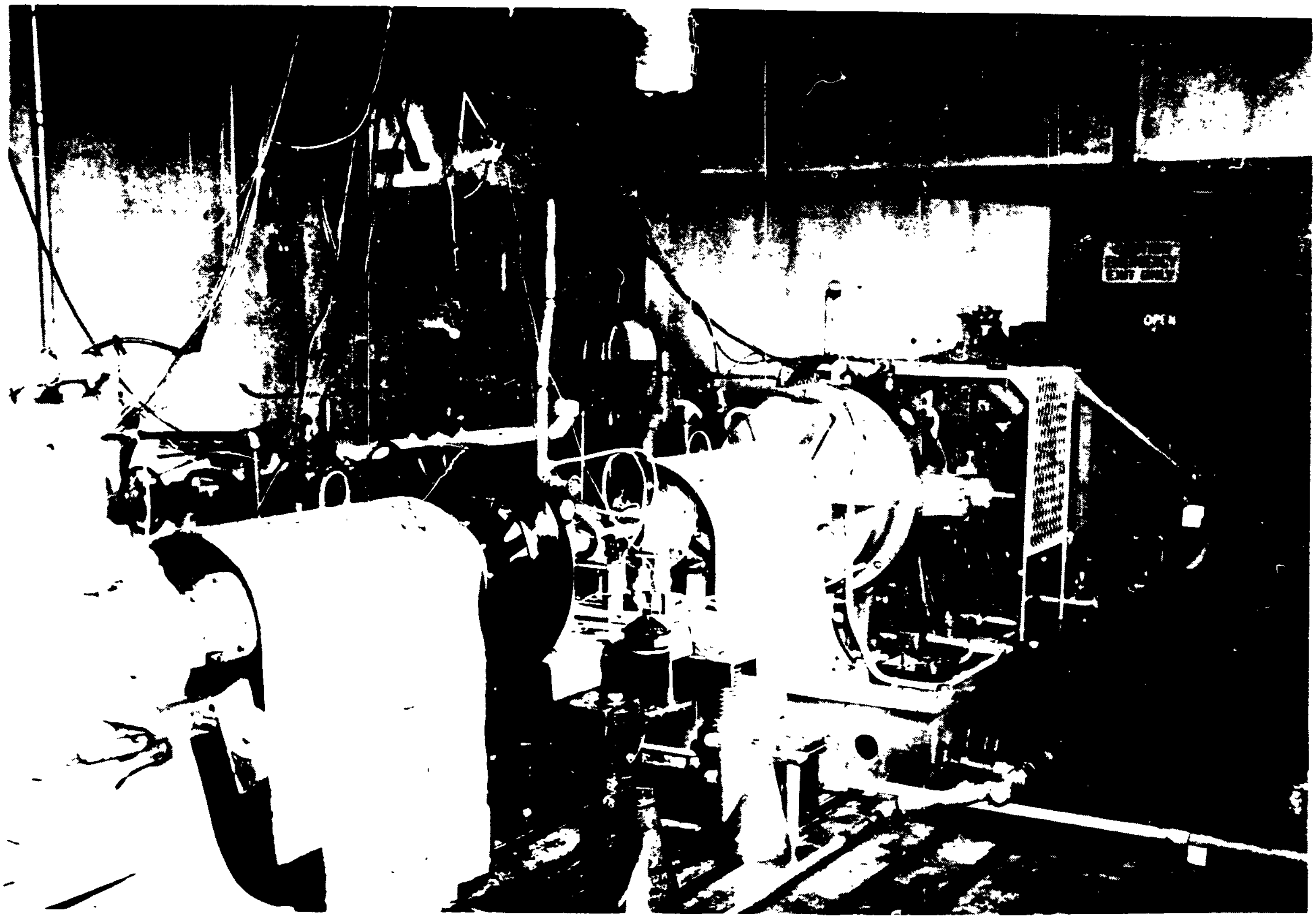
Inclosure 5



TEST SETUP OF CODE T-22 FLUID COUPLING,

FIGURE 6

Inclosure 6



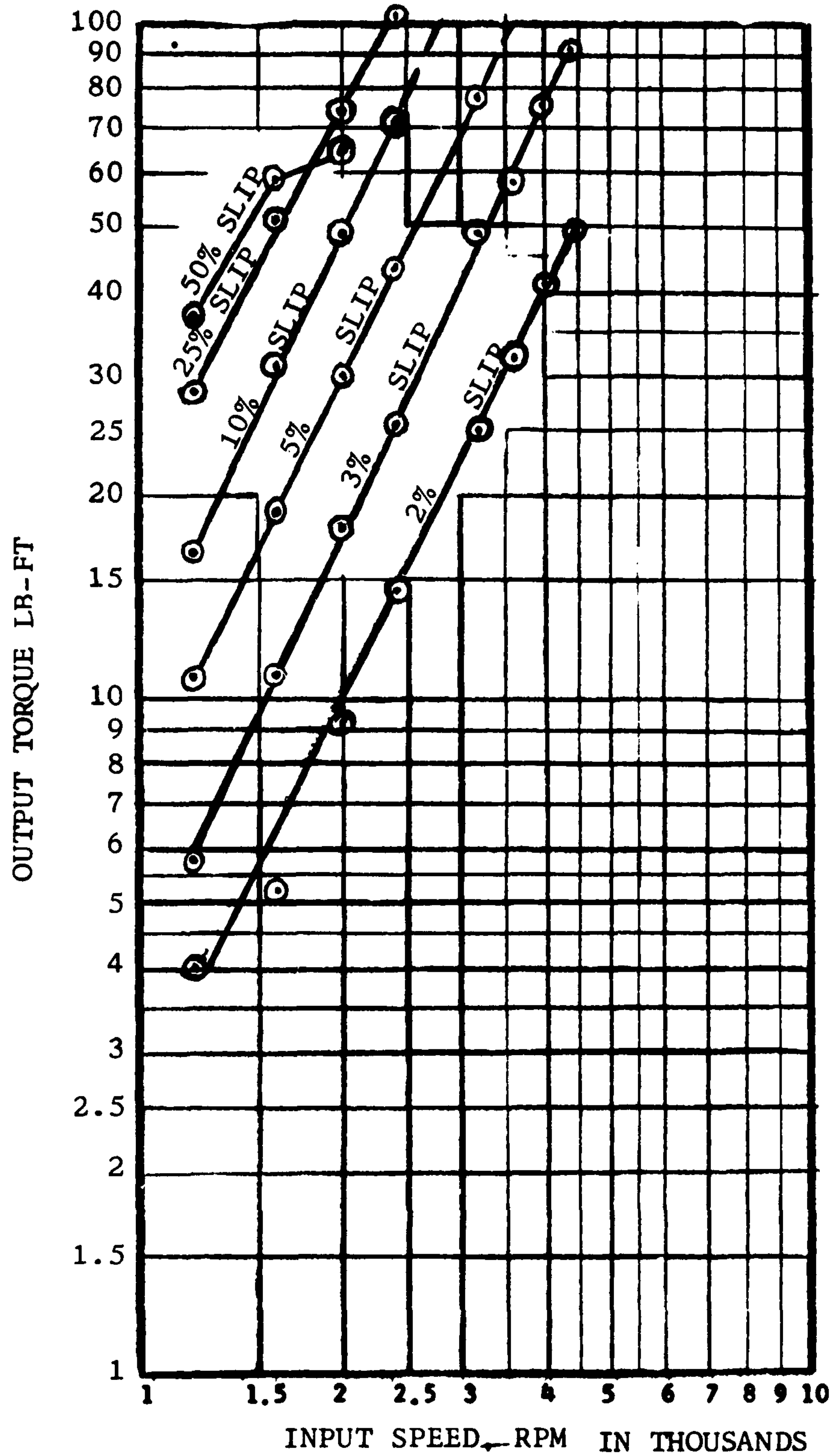
TEST SETUP OF CODE T-22 FLUID COUPLING,

FIGURE 7

Inclosure 8

OUTPUT TORQUE CHARACTERISTICS OF CODE
T-22 FLUID COUPLING

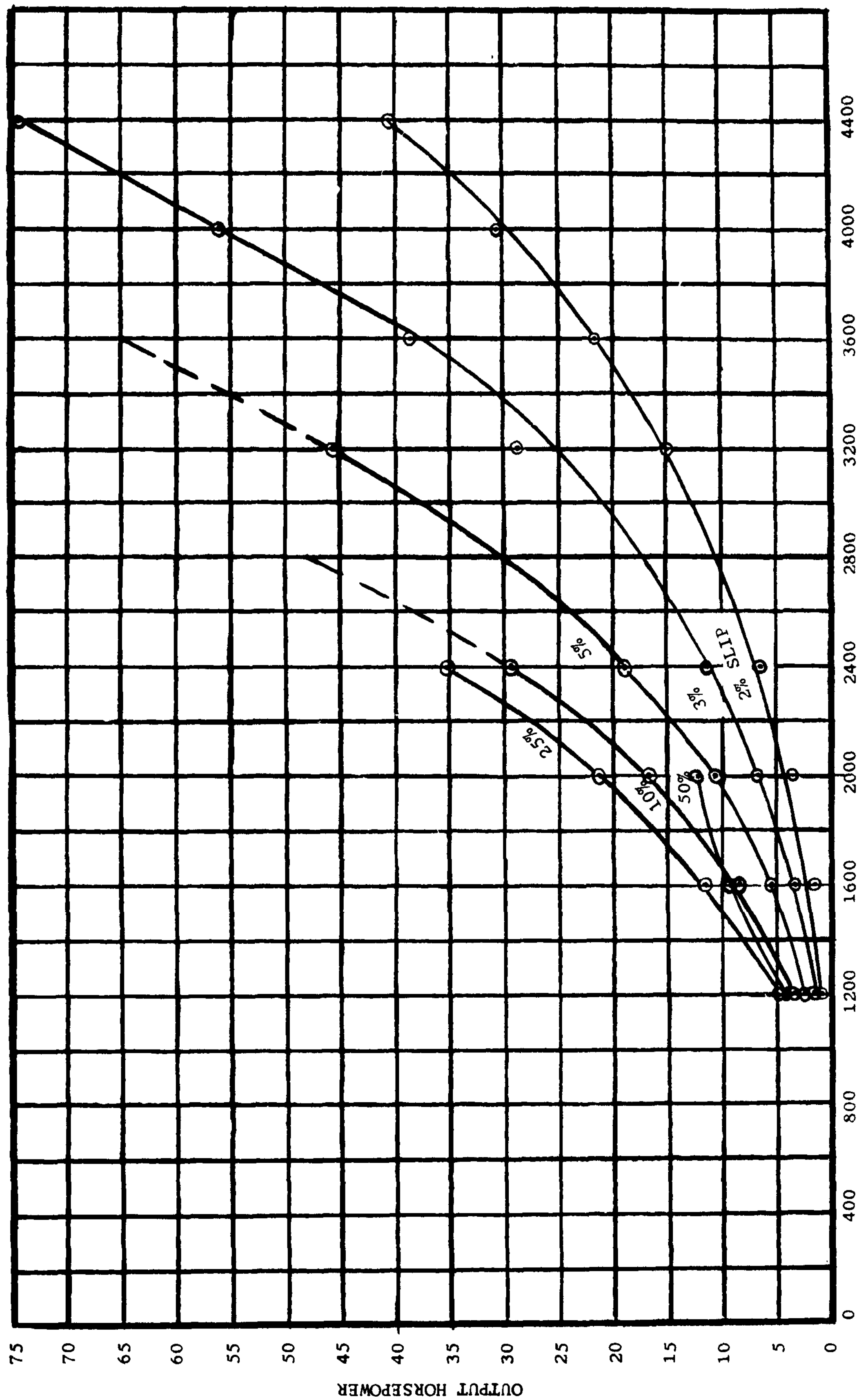
FIGURE 8



OUTPUT TORQUE CHARACTERISTICS OF CODE
T-22 FLUID COUPLING

FIGURE 9

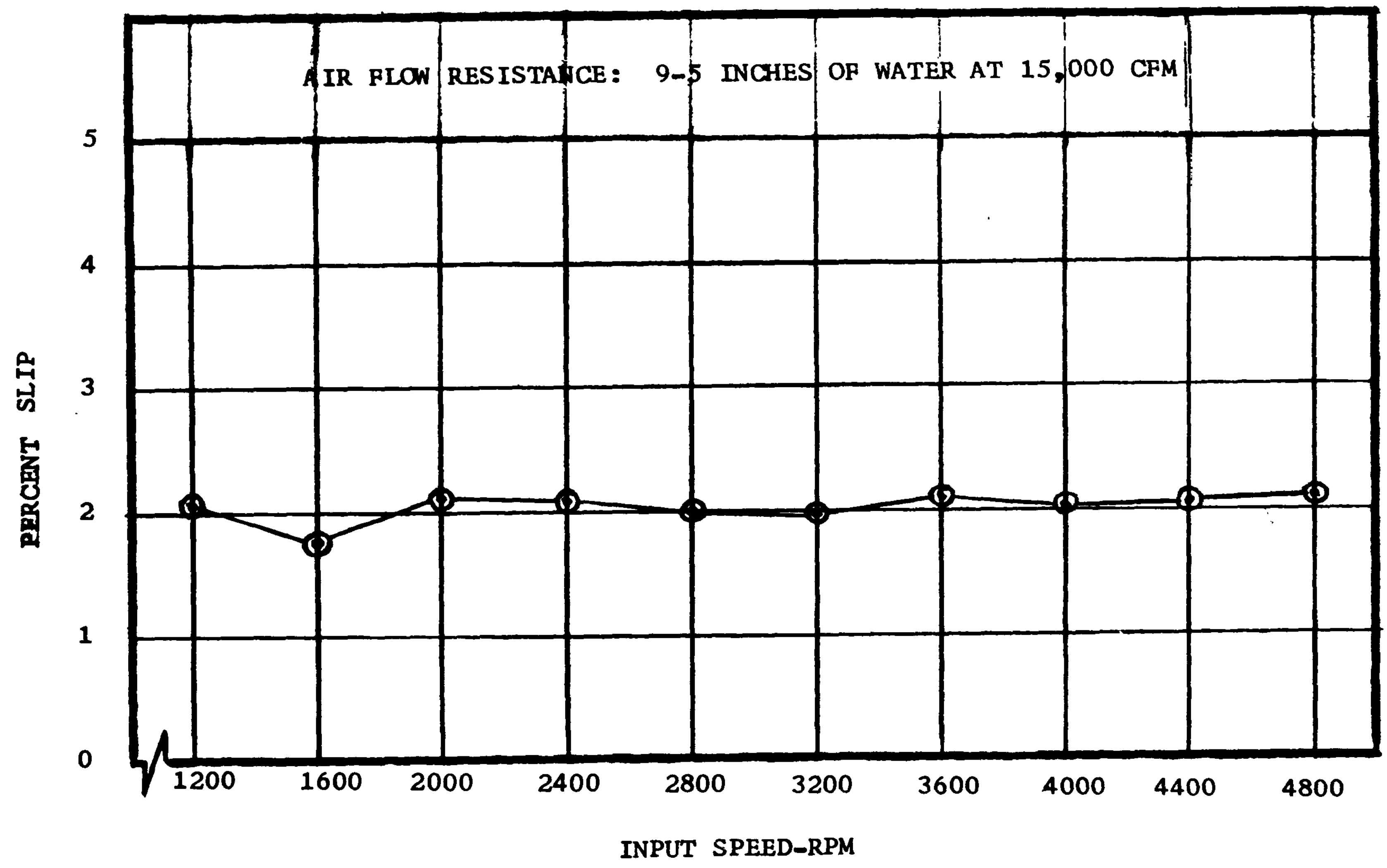
Inclosure 9



OUTPUT HORSEPOWER CHARACTERISTICS OF
CODE T-22 FLUID COUPLING

FIGURE 10

Inclosure 10



PERCENT SLIP OF CODE T-22 FLUID COUPLING
DRIVING CODE F-78 FAN

FIGURE 11

DISPOSITION FORM

SECURITY CLASSIFICATION (If any)

FILE NO.	SUBJECT
SMOTA-RPO	Evaluation of Variable Speed Fan Drive Assembly

TO SMOTA-RB
SMOTA-RX

FROM Ch, SMOTA-RPO

DATE 19 Sep 62

COMMENT NO. 1

IMShear/bg/33284

Program authority is provided to conduct testing of one (1) variable speed liquid drive fan assembly.

a. SMOTA-RB charge cost

Labor "11"
Material "99"
TOTAL

b. SMOTA-RX charge cost to 3717-0133:

Labor "11"
Material "99"
TOTAL

c. Priority "A".

d. Target completion date: January 1963

REF: SMOTA-RB Cost Est. #2962

R E Wyman

R. E. WYMAN
Chief, Plans & Program Branch

1 Incl
DF, 10 Aug 62

CC: SMOTA-OF(X)
SMOTA-OM(X)
SMOTA-REC, H. Fedorchuk

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AD ______ ACCESSION NO. ______ UNCLASSIFIED

Power Plant Laboratory, Detroit Arsenal
PERFORMANCE OF CODE T-22 TEMPERATURE CONTROLLED, VARIABLE SPEED FLUID COUPLING FOR FAN DRIVE.
Carl Lorentzen
Report No. 7964 (Final) - 13 pp-Illus-photographs and graphs
Unclassified Report

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Method: Dynamometers were used to determine output horsepower and torque characteristics with respect to input speeds. With fluid coupling driving Code F-78 fan the following was determined: a. Responses of fording and temperature controls. b. Endurance testing was completed for 100 hours at fan speeds from 1200 to 2800 rpm.

Results: a. Performance of Code T-22 fluid coupling was as follows: (1) Output torque was 49 lb-ft at 2 percent slip with input speed at 4400 rpm and 91 lb-ft at 3 percent slip. (2) Output horsepower was 40 at 2 percent slip with input speed at 4400 rpm and 74 at 3 percent slip. (3) The slip was 2 percent when driving Code F-78 fan at input speeds from 1200 to 4800 rpm. b. The temperature control started increase of fan speed at 187F. c. Response time of funding control was a maximum of 22 seconds to reduce fan speed from 4710 to 450 rpm. d. Code T-22 fluid coupling withstood the 100 hr endurance test without any failures.

Conclusions: The performance and durability of Code T-22 variable speed fluid coupling was satisfactory. The control system as provided was unreliable. The control as modified functions but durability was not determined.

Recommendations: Redesign control system and test for durability and reliability. Conduct a test of cooling control on a power package.

Performance of Code T-22 Temperature Controlled, Variable Speed Fluid Coupling for Fan Drive

JUL 15 '63

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AD ______ ACCESSION NO. ______ UNCLASSIFIED

Power Plant Laboratory, Detroit Arsenal
PERFORMANCE OF CODE T-22 TEMPERATURE CONTROLLED, VARIABLE SPEED FLUID COUPLING FOR FAN DRIVE.
Carl Lorentzen
Report No. 7964 (Final) - 13 pp-Illus-photographs and graphs
Unclassified Report

Purpose: Determine the following performance characteristics of Code T-22 variable speed fluid coupling: a. Output horsepower and torque at input speeds from 1200 to 4000 rpm with 2, 3, 5, 10, 25 and 50 percent slip. b. Percent slip driving F-78 fan at simulated loads. c. Responses of fording and temperature controls. d. Endurance.

Method: Dynamometers were used to determine output horsepower and torque characteristics with respect to input speeds. With fluid coupling driving Code F-78 fan the following was determined: a. Responses of fording and temperature controls. b. Endurance testing was completed for 100 hours at fan speeds from 1200 to 2800 rpm.

Results: a. Performance of Code T-22 fluid coupling was as follows: (1) Output torque was 49 lb-ft at 2 percent slip with input speed at 4400 rpm and 91 lb-ft at 3 percent slip. (2) Output horsepower was 40 at 2 percent slip with input speed at 4400 rpm and 74 at 3 percent slip. (3) The slip was 2 percent when driving Code F-78 fan at input speeds from 1200 to 4800 rpm. b. The temperature control started increase of fan speed at 187F. c. Response time of funding control was a maximum of 22 seconds to reduce fan speed from 4710 to 450 rpm. d. Code T-22 fluid coupling withstood the 100 hr endurance test without any failures.

Conclusions: The performance and durability of Code T-22 variable speed fluid coupling was satisfactory. The control system as provided was unreliable. The control as modified functions but durability was not determined.

Recommendations: Redesign control system and test for durability and reliability. Conduct a test of cooling control on a power package.

Performance of Code T-22 Temperature Controlled, Variable Speed Fluid Coupling for Fan Drive

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